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Composition and vulnerability of bottomland hardwood forests of the Coastal Plain Province in the south central United States

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ABSTRACT

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A past history of declines in forest area affirms the need for documentation on the extent and species composition of today's bottomland hardwood ecosystem. This paper summarizes the forest composition and related vulnerability of bottomland hardwood forests using data from the many existing resource bulletins and the current inventory data base maintained by the USDA Forest Service. These forests support a complex mix of tree species. The 6.1 million-ha ecosystem is common in three physiographic sections of the Province. The East and West Gulf sections are typified by moist-site cover types, with stands widely dispersed. The Mississippi Alluvial Plain contains both moist- and wet-site cover types. Southern portions of the Mississippi Alluvial Plain are characterized by wet-site cover types with stands being concentrated spatially. Cover types are susceptible to varying degrees of human-induced disturbance, which may ultimately lead to permanent removal of forest cover.

INTRODUCTION

Bottomland hardwoods contribute ecological richness and an abundance of other resource values to the landscape of the southern United States (Wharton et al., 1982). In spite of their importance, there is a general shortage of literature describing the ecosystem from a regional perspective, particularly for the south central United States. Existing reports concentrate on the Mississippi Delta, fragment important physiographic boundaries by focusing on political sub-divisions, or have limited ecological scope.

This paper summarizes the forest composition and related vulnerability of bottomland hardwood forests. Vulnerability is defined as the potential for future loss of forest cover. Data from the many existing resource bulletins and the current inventory data base maintained by the USDA Forest Service are used for analysis. After summarizing historical trends and land-use information, the species composition and distribution of bottomland hardwood for-

ests of the Coastal Plain Province are examined. Lastly, conclusions regarding the diversity and potential vulnerability of this important ecosystem are discussed.

STUDY REGION

The region of study is the Coastal Plain Province covering part or all of seven south central States, including Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas (Fig. 1). Fennemann (1938) describes three physiographic sections of the Coastal Plain: the East Gulf Coastal Plain, the Mississippi Alluvial Plain, and the West Gulf Coastal Plain. Most noteworthy is the Mississippi Alluvial Plain, which encompasses major river lowlands located along the original floodplain of the Mississippi River. Bottomland hardwood forests of the East and West Gulf Coastal Plains are on low poorly drained sites along the many rivers and streams flowing through the area.

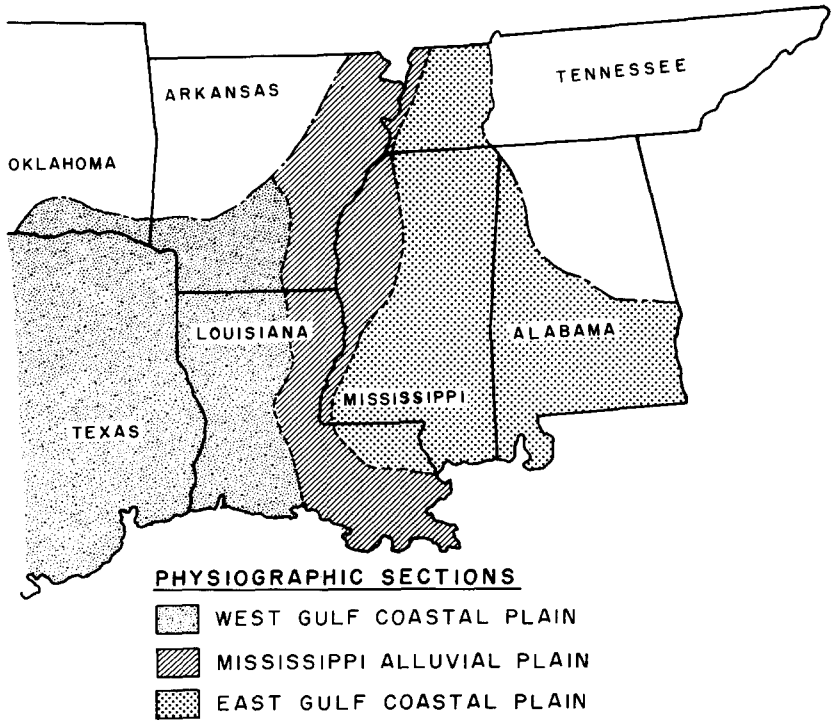


Fig. 1. Physiographic sections of the Coastal Plain Province in the south central United States (adapted from Fennemann, 1938).

METHODS AND MATERIALS

Data sources

Source data are from the continuous forest inventory conducted by the USDA Forest Service, Forest Inventory and Analysis (FIA) project. The FIA inventories began in the 1930's and have used measurement procedures that are relatively comparable through time. Historical data were taken from previously published reports and FIA archives (Anonymous, 1937, 1950, 1952, 1953, 1955, 1956, 1957, 1958; Cruikshank, 1938; Cruikshank and Eldridge, 1939; Sternitzke, 1960, 1962, 1963, 1965, 1967; Sternitzke and Van Sickle, 1968; Van Sickle and Van Hooser, 1969; Van Sickle, 1970; Murphy, 1972, 1973, 1975, 1976, 1977, 1978; Rudis and Birdsey, 1986). Some changes have occurred in sample design and compilation procedures, thus data were adjusted to be as consistent as possible with present standards. Current information was compiled using the most recent inventory data available (Van Hees, 1980; Birdsey, 1983; Rudis et al., 1984; Donner and Hines, 1987; Birdsey and May, 1988; McWilliams and Lord, 1988; Rosson et al., 1988). All of the data were measured in English units and then converted to SI units.

Sample scheme

The FIA inventory utilizes a systematic grid of sample plots spaced 4.8 km apart. In this study, a sub-sample of 2514 plots classified as bottomland hardwood was used to estimate current population parameters. Each plot was comprised of a cluster of 10 satellite points (except in Alabama and Louisiana where 5 were used). At each point, live trees at least 12.7 cm in diameter at breast height (D_{bh}) were selected for measurement by using a prism. Saplings (D_{bh} from 2.5 cm to 12.6 cm) were measured on fixed-radius plots centered around the first three points.

Timberland area estimates were based on photo-interpretation and ground checks of sample plots, as well as intensification plots interspersed between the sample plots. Factors derived from the area sample were used to expand per-ha estimates of tree weight, volume, basal area, and number. Tree volumes were calculated by using a combination of deterministic and regression estimates. Tree weights were derived from regional regression formulae (A. Clark, personal communication, 1985; Clark et al., 1985, 1986; Clark and Schroeder, 1986).

Forest cover-type definition

By definition, the bottomland hardwood ecosystem includes land at least 10% forested on bottomland sites where hardwood species make up at least

half the stocking of dominant and codominant trees and pines make up less than 25%. Stands where pines contribute 25–49% of the stocking are classified as pine/hardwood. Detailed cover types are assigned based on the stocking of key species (scientific names are listed in Tables 1–3). Bottomland hardwoods are a subset of the forested-wetlands ecosystem and comprise the bulk of the seasonally flooded basins and flats, and forested swamps as defined by the National Wetlands Inventory (Anonymous, 1984).

Bottomland hardwoods are divided into 12 cover types (Anonymous,

TABLE 1

Total[1] dry-weight, merchantable bole volume, basal area, and number of live trees by species and ranked by using total dry-weight as the importance value, East Gulf Coastal Plain[2]

Common and scientific names[3]	Total tree dry-weight (t)	Merchantable bole volume (m^3)	Basal area (m^2)	Number of trees
Water oak (*Quercus nigra*)	29.3	25.8	1.4	150.4
Sweetgum (*Liquidambar styraciflua*)	28.0	34.9	2.2	350.4
Black tupelo (*Nyssa sylvatica* var. *sylvatica*)	13.8	15.9	1.2	198.9
Green ash (*Fraxinus pennsylvanica*)	13.1	11.8	0.8	139.9
Willow oak (*Q. phellos*)	10.7	9.1	0.5	57.2
Sweetbay (*Magnolia virginiana*)	9.9	13.1	1.1	205.0
Hickory (*Carya* sp.)	9.7	8.0	0.5	80.6
Cherrybark oak (*Q. falcata* var. *pagodifolia*)	9.4	7.5	0.4	15.6
Red maple (*Acer rubrum*)	9.1	10.7	1.0	262.6
Swamp tupelo (*N. sylvatica* var. *biflora*)	8.4	10.0	0.7	75.1
Water tupelo (*N. aquatica*)	8.1	10.0	0.7	74.0
Yellow-poplar (*Liriodendron tulipifera*)	7.8	10.3	0.6	67.4
Other species	86.3	85.0	6.0	1079.8
All species	243.6	252.1	17.1	2756.9

[1]All values $\times 10^6$.
[2]Includes all live trees at least 2.5 cm in diameter at breast height. Eighty-one species with less than 3% of the importance value are combined in the 'other' category.
[3]According to Little (1978).

TABLE 2

Total[1] dry-weight, merchantable bole volume, basal area, and number of live trees by species and ranked by using total dry-weight as the importance value, Mississippi Alluvial Plain[2]

Common and scientific names[3]	Total tree dry-weight (t)	Merchantable bole volume (m^3)	Basal area (m^2)	Number of trees
Sugarberry (*Celtis laevigata*)	27.9	20.2	1.6	222.9
Bald cypress (*Taxodium distichum* var. *distichum*)	24.7	42.3	2.4	111.3
Green ash (*Fraxinus pennsylvanica*)	23.5	19.0	1.5	229.1
Water tupelo (*Nyssa aquatica*)	23.0	26.1	2.0	119.4
Sweetgum (*Liquidambar styraciflua*)	19.6	23.8	1.4	121.7
Overcup oak (*Quercus lyrata*)	18.1	11.3	0.8	80.0
Willow (*Salix* sp.)	16.2	19.3	1.2	75.4
Water hickory (*Carya aquatica*)	15.6	10.7	0.8	131.6
Nuttall oak (*Q. nuttallii*)	13.4	10.6	0.6	30.4
Willow oak (*Q. phellos*)	12.3	9.6	0.6	54.4
Water oak (*Q. nigra*)	11.5	9.5	0.5	37.5
Cottonwood (*Populus* sp.)	7.9	9.8	0.4	16.4
Red maple (*Acer rubrum*)	7.6	9.2	1.0	282.7
American elm (*Ulmus americana*)	7.0	7.1	0.6	99.3
Other species	41.0	35.5	2.8	551.3
All species	269.3	264.0	18.2	2163.4

[1]All values $\times 10^6$.
[2]Includes all live trees at least 2.5 cm in diameter at breast height. Fifty-nine species with less than 3% of the importance value are combined in the 'other' category.
[3]According to Little (1978).

1972). Cover types are assigned on the basis of plurality of dominant and codominant species. The definitions of cover types follow Putnam's (1951) guidelines for southern bottomland forest types. Naming conventions are those established in 1954 by the Society of American Foresters (SAF; Anonymous,

TABLE 3

Total[1] dry-weight, merchantable bole volume, basal area, and number of live trees by species and ranked by using total dry weight as the importance value, West Gulf Coastal Plain[2]

Common and scientific names[3]	Total tree dry-weight (t)	Merchantable bole volume (m^3)	Basal area (m^2)	Number of trees
Sweetgum (*Liquidambar styraciflua*)	28.4	35.6	2.1	263.2
Water oak (*Quercus nigra*)	27.0	22.8	1.3	99.8
Willow oak (*Q. phellos*)	21.0	16.0	1.5	83.3
Overcup oak (*Q. lyrata*)	15.3	9.9	0.7	62.3
Cherrybark oak (*Q. falcata* var. *pagodifolia*)	10.2	8.6	0.4	21.5
Green ash (*Fraxinus pennsylvanica*)	8.7	7.3	0.6	183.1
Black tupelo (*Nyssa sylvatica* var. *sylvatica*)	7.8	8.5	0.7	129.0
Bald cypress (*Taxodium distichum* var. *distichum*)	7.8	12.6	0.8	49.4
Water hickory (*Carya aquatica*)	7.3	5.6	0.4	68.5
Water tupelo (*N. aquatica*)	7.2	7.9	0.6	54.0
Laurel oak (*Q.laurifolia*)	6.3	4.4	0.3	26.2
Loblolly pine (*Pinus taeda*)	5.9	8.7	0.4	21.9
Sugarberry (*Celtis laevigata*)	5.8	4.5	0.4	65.5
Other species	67.4	61.2	4.9	1217.9
All species	226.1	213.6	15.1	2345.6

[1]All values $\times 10^6$.
[2]Includes all live trees at least 2.5 cm in diameter at breast height. Seventy-four species with less than 3% of the importance value are combined in the 'other' category.
[3]According to Little (1978).

1954). For comparability, FIA cover-type names were not changed when the SAF updated its naming conventions in 1980.

RESULTS AND DISCUSSION

Historical trends

The decline in area of bottomland hardwood forests has been well docu-

mented (Sternitzke, 1976; MacDonald et al., 1979; Turner and Craig, 1980; Turner et al., 1981), especially for the Mississippi Alluvial Plain. Analysis of detailed cover types is not possible because of inconsistent definitions of the early inventories. Definition of the broad-type bottomland hardwoods has been consistent from inventory to inventory. Turner et al. (1981) and Frayer and Beltz (1985) discuss using FIA data in a historical context.

Based on the earliest FIA inventories, completed between 1934 and 1948, bottomland hardwood forests of the South Central Coastal Plain totaled 8.3 million ha (Fig. 2). Over half of the bottomland hardwoods were on the Mississippi Alluvial Plain. The current estimate totals 6.1 million ha, a loss of 2.2 million ha since the inventories began. Nearly all of the loss was due to clearing and draining of Mississippi Alluvial Plain forests, with the largest decreases occurring in the 1940's and from the 1960's to the early 1970's.

Bottomland forests of the East and West Gulf sections have remained stable over time. Between the two earliest inventory periods, the area of bottomland hardwoods increased in the East Gulf. This is attributed to shifts from loblolly-pine/hardwood to pure-hardwood forests following extensive selective logging of pine during the 1940's (Anonymous, 1953).

Data from the two most recent inventory periods indicate that declines in the area of bottomland hardwood forests, at least for the present, have slowed.

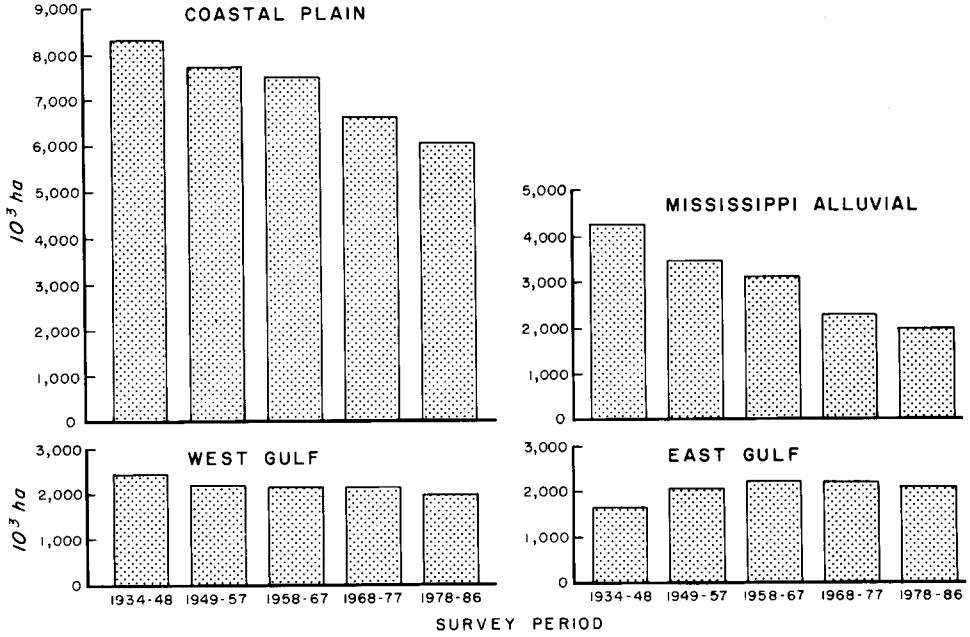


Fig. 2. Recent historical trends in the area of bottomland hardwood timberland.

TABLE 4

Coastal Plain Province[1] by land use and physiographic section

Land use	Total	Physiographic section		
		East Gulf	Mississippi Alluvial	West Gulf
Bottomland hardwoods	6062.9	2098.1	1994.6	1970.2
Other forest	21627.3	11117.9	607.7	9901.7
Total forest	27690.2	13216.0	2602.3	11871.9
Non-forest	25087.3	8069.3	8312.2	8705.8
Total land	52777.5	21285.3	10914.5	20577.7

[1]ha $\times 10^3$.

A shortage of drainable tracts, a general agricultural surplus, and depressed oil markets have contributed to the slowdown.

Land use

About one-half of the Coastal Plain Province is forested (Table 4). One-fifth of this total forest is occupied by bottomland hardwoods that are distributed in roughly equal amounts among the three physiographic sections.

The Mississippi Alluvial Plain is the least-forested section because non-forest land use, mostly agriculture, predominates on three-fourths of the land area. Bottomland hardwoods contribute most of the forest cover. Other forests consist of upland pine and hardwood types located on well-drained sites and in fringe areas.

The East and West Gulf sections are 60% forested, and upland pine and hardwood forests dominate these sections. Less than one-fifth of the forest area in these sections is comprised of bottomland hardwood forest.

Species importance

The relative importance of individual tree species highlights forest composition of the three physiographic sections. Detailed data on species importance are given in Tables 1–3. The total number of species and the distribution of total biomass among species indicate the high diversity of bottomland hardwood forests. Using these as a basis, the East and West Gulf sections are slightly more diverse than the Mississippi Alluvial Plain, due to the wide range of physiographic conditions in these sections.

Sweetgum and water oak dominate the east and West Gulf sections, with

about one-quarter of the total biomass in each. Other oak species, ash, and black tupelo are also dominant species. Sweetbay, red maple, swamp tupelo, and yellow poplar are common in the East Gulf section. Bald cypress, water hickory, loblolly pine, and sugarberry occur more frequently in the West Gulf section.

Sugarberry, bald cypress, and green ash dominate the Mississippi Alluvial Plain, followed by water tupelo, sweetgum, and overcup oak. Combined, these species form one-half of this section's total biomass. Willow, cottonwood, and American elm are other common species.

Forest cover types

The most common bottomland hardwood cover type of the Coastal Plain is sweetgum/Nuttall-oak/willow-oak, which occupies one-third of the bottomland hardwood forest area. Sugarberry/American-elm/green-ash, usually a temporary type following disturbance (Putnam, 1951), is second with about one-fifth of the forest area. Together, these two types form over half of the bottomland hardwood forest. Swamp-chestnut-oak/cherrybark-oak, the most highly prized type for quality timber, now ranks third in forest area. In the 1940's, the area of this type ranked second only to the sweetgum/Nuttall-

TABLE 5

Bottomland hardwood timberland[1] by cover type[2] and physiographic section

Cover type	Total	Physiographic section		
		East Gulf	Mississippi Alluvial	West Gulf
Swamp-chestnut-oak/cherrybark-oak	837.5	430.0	30.3	377.2
Cottonwood	76.9	16.2	51.7	9.0
Sweetgum/Nuttall-oak/willow-oak	2051.8	742.5	433.2	876.1
Sugarberry/American-elm/green-ash	1086.1	318.2	534.1	233.8
Riverfront hardwoods[3]	232.4	89.5	84.0	58.9
Willow	234.1	38.3	162.9	32.9
Overcup-oak/water-hickory	496.5	55.6	247.8	193.1
Cypress/tupelo	648.7	109.7	396.3	142.7
Sweetbay/swamp-tupelo/red-maple[4]	398.9	298.1	54.3	46.5
Total bottomland hardwoods	6062.9	2098.1	1994.6	1970.2

[1]ha $\times 10^3$.
[2]Ranked from moist-site to wet-site types according to the Society of American Foresters (1954).
[3]Consists mostly of the sycamore/pecan/American-elm cover type, but includes some river-birch/sycamore and black-ash/American-elm/red-maple stands.
[4]Includes 4900 ha of the Atlantic-white-cedar cover type.

oak/willow-oak type (Putnam, 1951). Cypress/tupelo is the fourth most common type. This type plus the first three types compose three-fourths of the bottomland hardwood forest. All the remaining types occupy less than 10% each.

In Table 5, individual cover types are ranked on a continuum from moist to wet (Anonymous, 1954). Species richness is related to this continuum (Putnam et al., 1960; McKnight et al., 1981). With some exceptions, such as cottonwood, cover types on moist sites contain a more diverse mix of species than those on wet sites. The most diverse are the swamp-chestnut-oak/cherrybark-oak, sweetgum/Nuttall-oak/willow-oak, and sugarberry/American-elm/green-ash cover types.

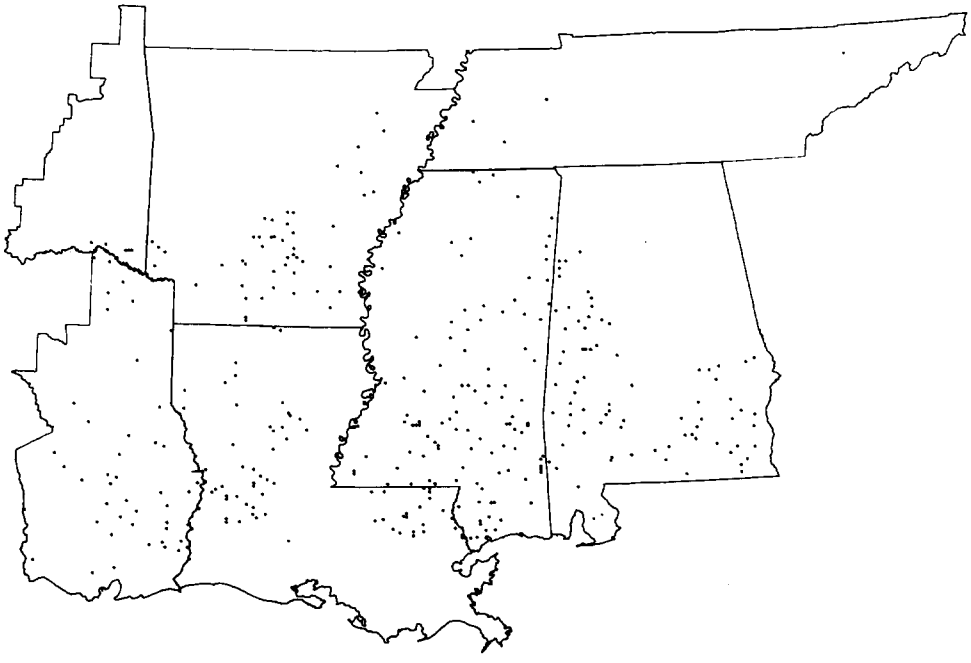
Cover-type names can be misleading from the standpoint of actual species composition (Putnam et al., 1960). For example, 10 species contribute 60% of the total basal area of the swamp-chestnut/cherrybark-oak type. In this case, Putnam's (1951) white-oak/red-oak/other-hardwood nomenclature would probably be more appropriate. On wetter sites, less diverse types such as willow and cypress/tupelo are common. In these types, the two key species dominate total basal area. The most diverse type on wet sites is the overcup-oak/water-hickory type, which has five species making up 60% of the total basal area.

Like diversity, vulnerability of today's bottomland hardwood forests is closely correlated with the moisture continuum. Stands on moist sites are more vulnerable to clearing for other land uses than those on wet sites. Although wet sites are less vulnerable, in some areas they are subject to disturbance from canal building and channelization. Such has been the case in the Atchafalaya and Barataria basins in Louisiana, particularly during times of high oil prices. Declines in the area of bottomland hardwood forests affect the ecological diversity of the resource. Loss of diversity is compounded because the more vulnerable cover types usually contain the widest assortment of species.

Distribution of cover types

The location of bottomland hardwood cover types varies across the Coastal Plain Province (Fig. 3a–h). Spatial-distribution patterns illustrate species composition and vulnerability. Cover types that are common on moist sites differ in geographic distribution. Swamp-chestnut-oak/cherrybark-oak forests are concentrated on the East and West Coastal Plain sections. The type is in highest concentrations in the southern portions of these sections. Cottonwood, the least-abundant type, exists mostly on the Mississippi Alluvial Plain. Sweetgum/Nuttall-oak/willow-oak is the most widely dispersed cover type. It is more common on the East and West Gulf Coastal Plains than on the Mississippi Alluvial Plain. Sugarberry/American-elm/green-ash stands are heavily concentrated on the Mississippi Alluvial Plain and also along major

a. SWAMP-CHESTNUT-OAK / CHERRYBARK-OAK



b. COTTONWOOD

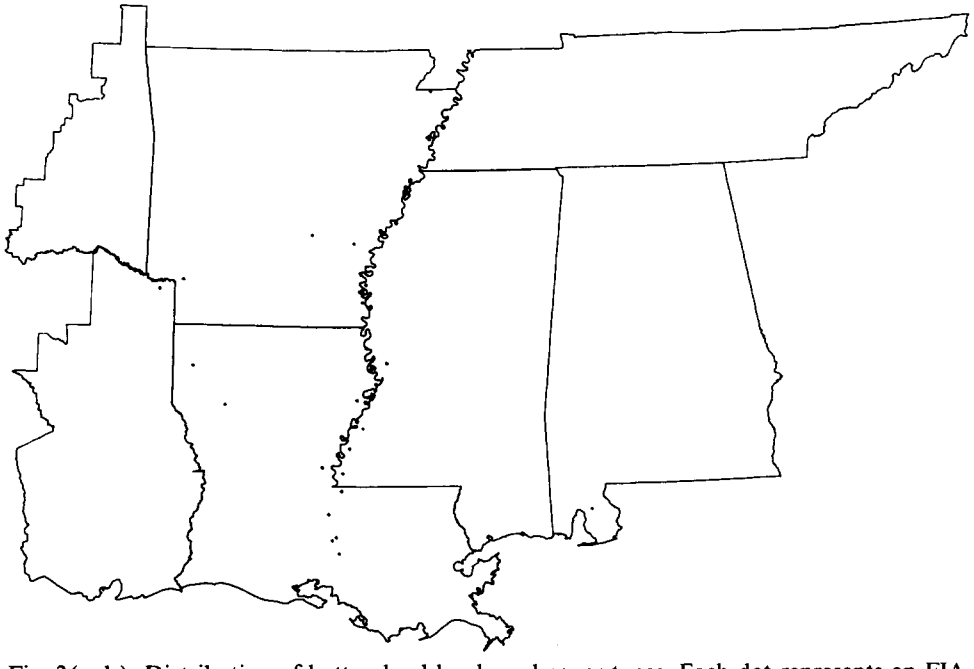
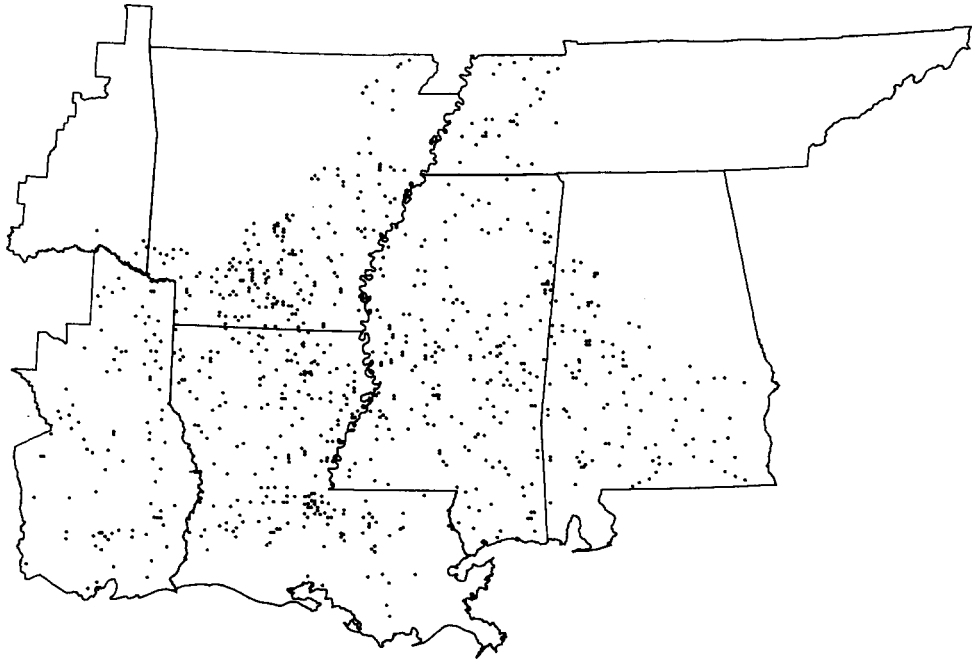
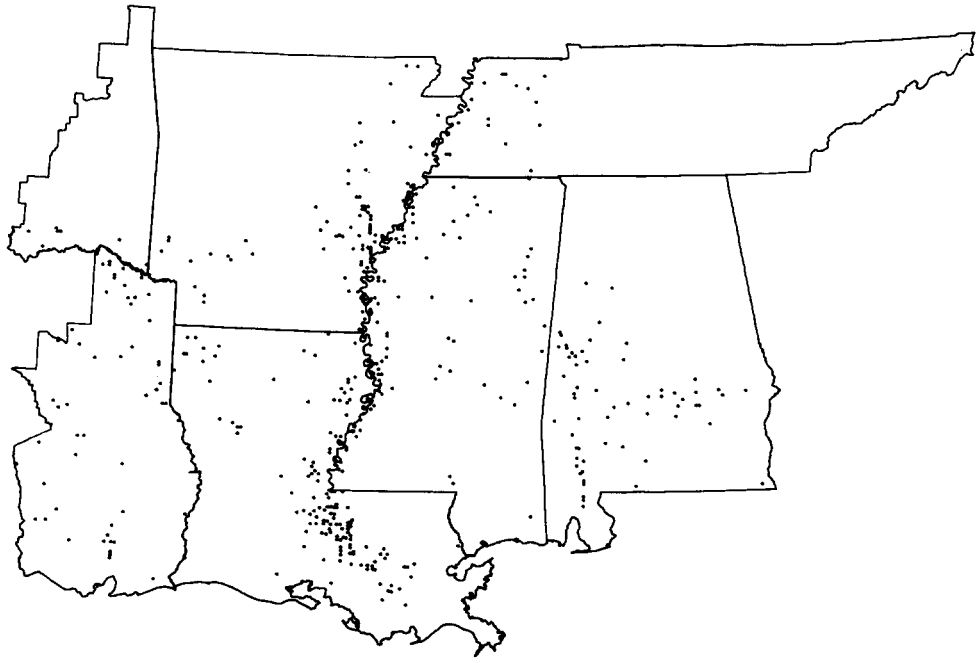


Fig. 3(a–h). Distribution of bottomland hardwood cover types. Each dot represents an FIA sample plot.

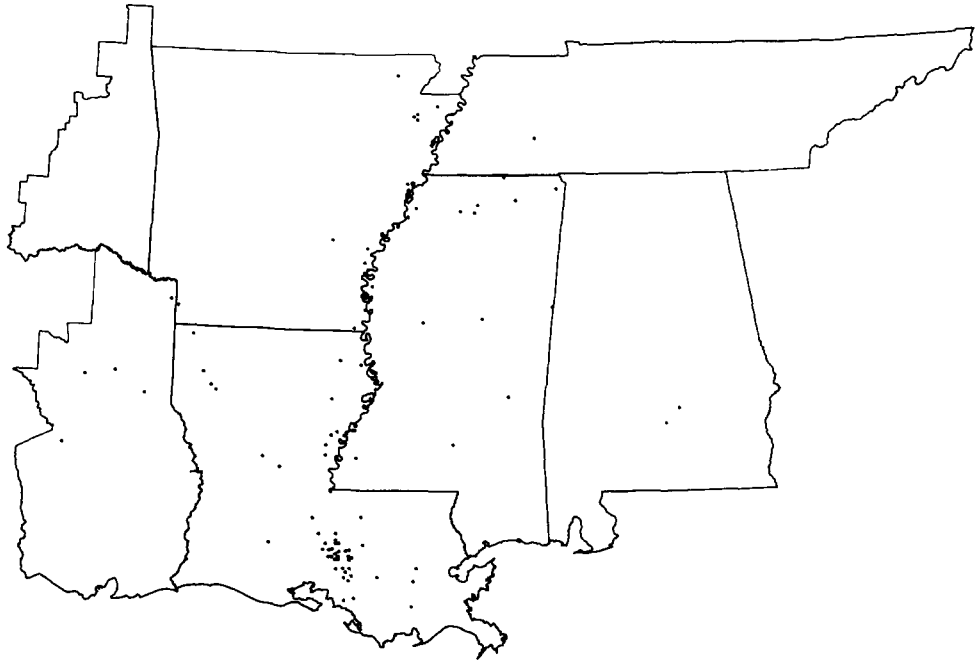
c. SWEETGUM / NUTTALL-OAK / WILLOW-OAK



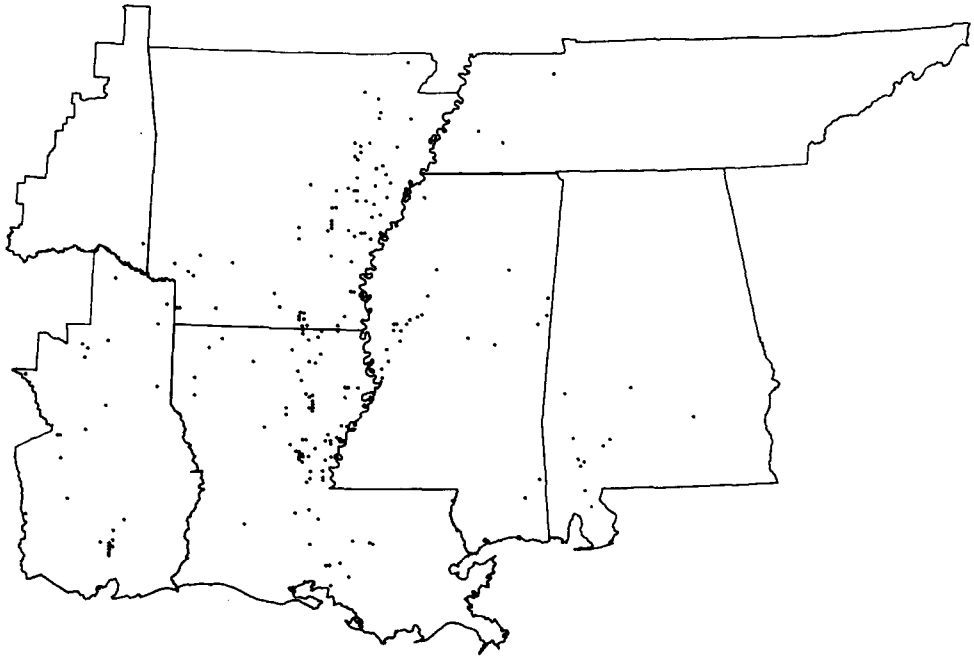
d. SUGARBERRY / AMERICAN-ELM / GREEN-ASH



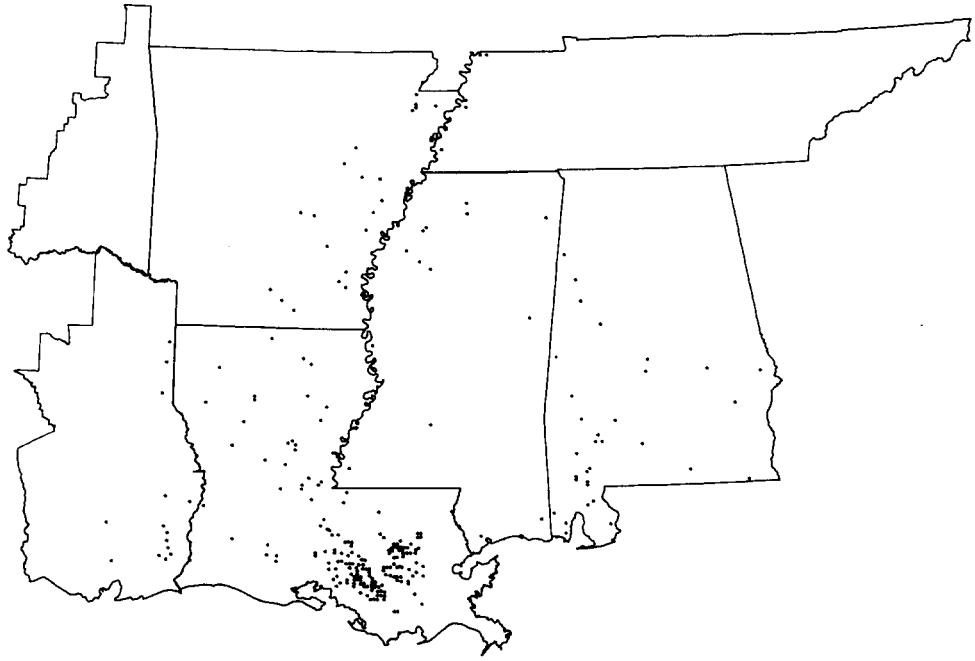
e. WILLOW



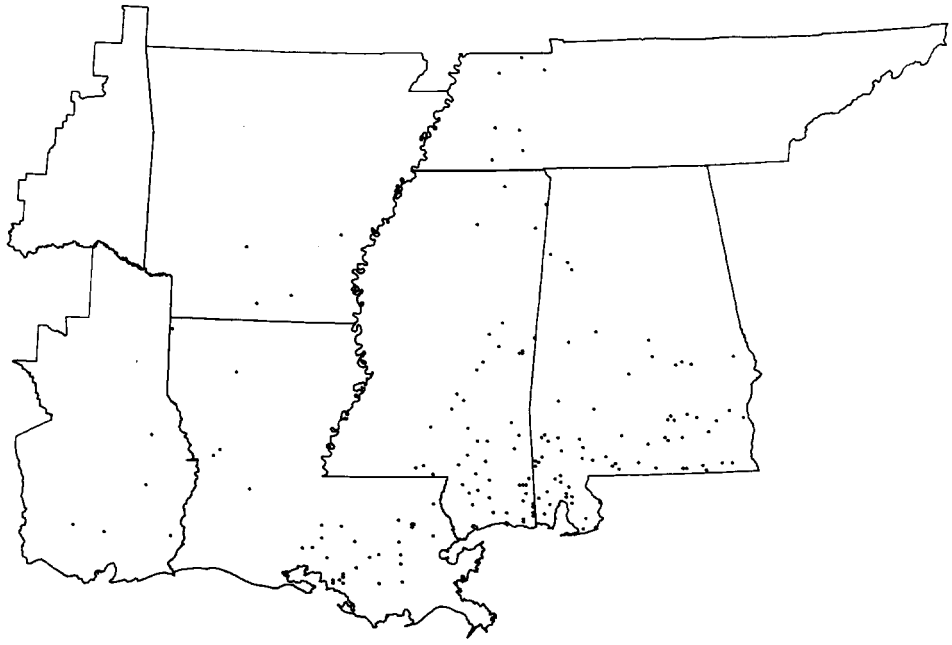
f. OVERCUP-OAK / WATER-HICKORY



g. CYPRESS / TUPELO



h. SWEETBAY / SWAMP-TUPELO / RED-MAPLE



river basins of the other sections, such as the Arkansas, Red, Tombigbee, and Alabama Rivers.

Cover types on wet sites tend to have more limited distribution, most commonly on the Mississippi Alluvial Plain. Willow occurs sporadically along the Mississippi River, most notably in southern Louisiana. Overcup-oak/water-hickory is common adjacent to and west of the Mississippi River. Cypress/tupelo, the most extensive of the wet types, is common along all the major river courses. Over half of the cypress/tupelo stands are concentrated in southern Louisiana. Sweetbay/swamp-tupelo/red-maple forests are most abundant in the southern part of the East Gulf Coastal Plain.

CONCLUSION

Though bottomland hardwood forests are much more dispersed outside the Mississippi Alluvial Plain, they are an important source of ecological diversity in all sections of the Coastal Plain Province.Trends indicate that declines in area have slowed, but changes in market conditions of the agricultural or oil economies could certainly reverse the situation. The most diverse types, which occur on moist sites, are also the most vulnerable to clearing for agriculture. This potential loss of diversity is offset somewhat because such stands are the most abundant and scattered of the bottomland hardwood cover types. Canal building and channelization threaten cover types common on wet sites. The potential loss of diversity is less of a problem with these types; however, their more limited spatial distribution makes them susceptible to endangerment or near-extinction should economic conditions change significantly. For example, a rise in oil prices could cause a resurgence of oil exploration activity in southern Louisiana, thus negatively affecting cypress/tupelo forests.

Increased public awareness has helped stem the loss of valuable bottomland ecosystems. Purchase of timberland reserves by public agencies and the privately funded Nature Conservancy are examples of positive forces. Moreover, forest management, particularly in the area of regeneration, offers an important opportunity for improving the ecosystem.

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